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Colour, phenolic content and antioxidant capacity of some fruits dehydrated by a combination of different methods

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A B S T R A C T

The objective of this study was to improve product quality of dehydrated fruits (apple, pear, papaya, mango) using combined drying techniques. This involved investigation of bioactivity, colour, and sensory assessment on colour of the dried products as well as the retention of the bio-active ingredients. The attributes of quality were compared in regard to the quality of dehydrated samples obtained from continuous heat pump (HP) drying technique. It was found that for apple, pear and mango the total colour change (ΔE) of samples dried using continuous heat pump (HP) or heat pump vacuum-microwave (HP/VM) methods was lower than of samples dried by other combined methods. However, for papaya, the lowest colour change exhibited by samples dried using hot air–cold air (HHC) method and the highest colour change was found for heat pump (HP) dehydrated samples. Sensory evaluation revealed that dehydrated pear with higher total colour change (ΔE) is more desirable because of its golden yellow appearance. In most cases the highest phenol content was found from fruits dried by HP/VM method. Judging from the quality findings on two important areas namely colour and bioactivity, it was found that combined drying method consisted of HP pre-drying followed by VM finish drying gave the best results for most dehydrated fruits studied in this work as the fruits contain first group of polyphenol compounds, which preferably requires low temperature followed by rapid drying strategy.

1. Introduction

Consumers are health conscious and seeking for healthier natural foodstuffs in order to have a nutritious diet, and this lead to the increase of dietary intake of fruit. Fresh fruit contains vitamins, minerals and high amount of water. However, it has a short shelf life due to biochemical changes. To prolong fruit shelf life, postharvest processing of excessive fresh fruit, such as drying is widely used.

Processing of fruit into dried product using different drying medium and mode of heat input with more advance drying technology has been done by many researchers. Law, Waje, Thorat, and Mujumdar (2008) claimed that hot air, dehumidified air, freeze drying, vacuum drying and solar drying are useful in removing surface moisture, whereas microwave drying is useful for removing internal moisture.

Vacuum microwave drying, when appropriately applied, significantly reduces the drying time of biological material ensuring the high quality of dried product. The different ways of heat transfer and removing of moisture shaped the drying kinetics, microstructure and physical parameters of green peas dehydrated by a combination of heat pump fluidised bed atmospheric freeze drying and vacuum microwave drying (Zielinska, Zapotoczny, Alves-Filho, Eikevik, and Blaszczak, 2013). The particular drying methods and their combinations can help to obtain these attributes of the dried product which are typical for snack food (Huang & Zhang, 2012). Different dehydration techniques such as osmotic dehydration, vacuum drying, freeze drying, superheated steam drying, heat pump drying and their combinations have great scope for the production of high quality dried products (Sagar & Suresh Kumar, 2010).

Product quality of dehydrated fruits is a key feature, which has to be taken into consideration while optimisation of novel drying technologies consisted on the sequence of relevant pre-treatments and appropriate techniques of dehydration. It is also a key feature to determine the suitability of a dryer in drying of fruits as the physical properties of fruits may change if different drying technique is applied. Currently, degradation of the dehydrated fruit due to the application of drying is the major concern. It must be

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able minimise the physical properties change of fruit in order to increase the dried product marketability.

Physical appearance and total colour change (ΔE) are important physical properties of dehydrated fruit. It is important to visually assess the dehydrated fruit because the first judgment made by consumers on a food quality is by the physical appearance and colour. Abnormal colour or significant change in physical appearance will cause the product to be rejected by the consumer (Lopez et al., 1997). Change of colour after dehydration is because fruit contain high amounts of reducing sugars such as glucose, sucrose, fructose and carbohydrates. These reducing sugars might undergo Maillard reaction through the intervention of amino compounds during drying (Cornwell & Wrolstad, 1981). It has been reported that the Maillard reaction occurred after exposing to air drying at high temperature and long drying duration (Chou, Chua, Mujumdar, Hawlader, & Ho, 2000). In addition, the enzymatic reaction changed the dehydrated fruit colour to brown or darker colour due to the oxidation of phenols to *o*-quines (brown pigment or melanins) (Beveridge & Harrison, 1984). On the other hand, the solid matrix of the foodstuff is unable to support its own weight after drying, leading to drastic changes in physical structure (Ratti, 2001).

Colour is sensory parameter widely used to justify the consumer acceptance on dehydrated fruit. Some of the dehydrated fruits are extremely hard, burnt, off-flavour and tasteless due to improper drying. For instances, continuous hot air or high temperature drying causes quality degradation such as unnatural in colour, wrinkled, hard, bitter and burnt (Nijhuis et al., 1998). The appearance of rosehip and chempedak changed to dark brown colour after drying at high temperature due to browning reaction (Chong, Law, Cloke, Luqman Chuah, & Daud, 2008; Erenturk, Gulaboglu, & Gultekin, 2004). Thus far, comparison on physical appearance, colour and sensory assessment on colour of dehydrated fruit have not been reported yet.

The objective of this study was to improve product quality of dehydrated fruits by combined methods in terms of physical appearance, colour and well as bioactivity attributes such as total polyphenol contents and antioxidant capacity.

2. Materials and methods

2.1. Plant material

Apple (*Malus domestica*), pear (*Pyrus pyrifolia*), mango (*Mangifera indica*) and papaya (*Carica papaya*) were purchased from a fruit supplier in Semenyih, Selangor, Malaysia. Those fruits were cut into 15 mm cubes (Fig. 1) using a stainless steel knife before drying.

2.2. Drying procedure

The samples of 200 g were subject to heat pump (HP) drying, hot air–cold air (HHC) drying, hot air vacuum-microwave (H/VM) drying and heat pump vacuum-microwave (HP/VM) drying. Fruit cubes were dried until the equilibrium moisture content was achieved. During HP, HHC and H drying the weight loss of the samples were recorded using an electronic balance (Adventure OHAUS, AR3130, USA) with a range of 0–310 g and system error of ±0.001 g at intervals of 30 min for the first 60 min of drying. Then, the weight of samples was measured every 60 min. The processing parameters depended on the particular method of drying (Chong, Figiel, Law, & Wojdyło, 2013). During VM drying the weight of samples was measured at 3 min and 4 min intervals for 360 W and 240 W of microwave power respectively. The safe microwave power level applied for papaya was 360 W, while for apple, pear and mango was only 240 W. The preliminary study revealed that exceeding this safe microwave power resulted in burning of the samples.

2.3. Heat pump (HP) drying

Fruit cubes were placed in a single layer on a tray with mesh size of 0.5 cm × 0.5 cm in the middle of the drying chamber of heat pump dryer (iLab LT1000; The University of Nottingham, Selangor, Malaysia). Low temperature dehumidified air (LTDA) horizontally flew through the sample during drying process. The processing air temperature and relative humidity were 35 °C and 20%, respectively (Chong et al., 2013).

2.4. Hot air–cold air (HHC) drying

Hot air and cold air drying technique (iLab TS1000; The University of Nottingham, Selangor, Malaysia) is applied in drying of heat sensitive product. During drying by this technique using a convective dryer (Memmert, DO6836, Germany) the cold air can be supplied to the samples in the middle or at the beginning of drying process. This dryer allows tempering period to be conducted at temperature as low as 12 °C. It can also be classified as an intermittent dryer whereas cold air tempering can be applied at any stages of drying. For instance, cold air tempering period can be inserted between two hot air drying periods. In this study hot air (HA) of temperature 53.94 ± 0.03 °C was supplied continuously for the first two hours followed by two hours of cold air (CA) tempering (11.54 ± 0.26 °C) and thereafter hot air (HA) drying again until the equilibrium moisture content was achieved (Chong et al., 2013).

2.5. Heat pump vacuum-microwave (HP/VM) drying

The processing air temperature and relative humidity of the heat pump dryer (iLab LT1000; The University of Nottingham, Selangor, Malaysia) were 35 °C and 20%, respectively (Chong et al., 2013). The fruits were placed in a single layer on a perforated tray and pre-dried until the moisture content of dehydrated samples achieved 30%. Then, the samples were further dried using a vacuum-microwave dryer (SM Plazmatronika, Wroclaw, Poland).

2.6. Hot air vacuum-microwave (H/VM) drying

The fruit cubes were dried initially in a convective dryer (Memmert, DO6836, Germany) at 70 °C to 30% of moisture content (Chong et al., 2013). During this process fruit cubes were placed on a perforated tray separately. The direction of the air flux was perpendicular to the oven door. The velocity of the air approaching to the cubes was about 1 m/s. Then, the samples were further dried using a vacuum-microwave dryer at the same safe microwave power levels, which were applied during the HPP/VM drying.

2.7. Determination of moisture content

Moisture content (M) of dried fruits was calculated using Eq. (1):

$$M = \frac{W_f - W_t}{W_f} \tag{1}$$

where W_f is bone dry weight (g) and M_t is weight of sample at specific time (g).